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(54) Title: METHOD OF SELECTIVE PLASTIC EXPANSION OF SECTIONS OF A TUBING

(57) Abstract

A method of selective plastic expansion of sections of a tubing to create one or more recesses in the tubing with a larger diameter than that of the original tubing in which the tubing is radially symmetrically or asymmetrically expanded at one or more locations by application of a radial force to the interior of the tubing thereby inducing a plastic radial deformation of the tubing and removing said radial force from the interior of the tubing. The tubing can be a downhole tubing and the created recesses are preferably utilized to hold at least one downhole device, which is advantageously a gas lift mandrel or a sensor.

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METHOD OF SELECTIVE PLASTIC EXPANSION OF SECTIONS OF A TUBING

The invention relates to selective plastic expansion of tubings. More particularly the invention relates to selectively expanding a steel tubing to create recesses in the tubing by application of a radial force to the interior of the tubing.

Numerous methods and devices are known for expansion of tubings.

European patent specification 643794 discloses a method of expanding a casing against the wall of an underground borehole wherein the casing is made of a malleable material which preferably is capable of plastic deformation of at least 10% unaxial strain and the casing may be expanded by an expansion mandrel which is pumped, pulled or pushed through the casing.

Other expansion methods and devices are disclosed in German patent specification No. 1583992 and in US patent specifications Nos. 3,203,483; 3,162,245; 3,167,122; 3,326,293; 3,785,193; 3,499,220; 5,014,779; 5,031,699; 5,083,608 and 5,366,012.

Many of the known expansion methods employ an initially corrugated tube and the latter prior art reference employs a slotted tube which is expanded downhole by an expansion mandrel.

The use of corrugated or slotted pipes in the known methods serves to reduce the expansion forces that need to be exerted to the tube to create the desired expansion.

It is an object of the present invention to provide a method for selective expanding an at least partly solid, i.e. unslotted, tubing which requires exertion of a force

to expand the tubing and which provides a tubing having at one or more sections a larger diameter and possibly higher strength than the unexpanded tubing and which can be carried out with a tubing which already may have a tubular shape before expansion.

The present invention therefore relates to a method of selective plastic expansion of sections of a tubing to create one or more recesses (cavity bulges) in the tubing with a larger diameter than that of the original tubing in which the tubing is radially symmetrically or asymmetrically expanded at one or more locations by application of a radial force to the interior of the tubing thereby inducing a plastic radial deformation of the tubing and removing said radial force from the interior of the tubing.

The radial force to the interior of the tubing is preferably exerted by means of an expandable tool which has been moved through the tubing to the section which has to be expanded. The expandable tool is suitably an expandable mandrel, e.g. a cone or roller system which can be expanded at the intended location, but it may also be an expandable hydraulic packer or a steel reinforced bladder which can be expanded by using hydraulic pressure.

The expandable tool can advantageously be operated at an internal pressure of at least 200 bar. The selective plastic expansion according to the present invention can also be achieved through a localized explosion.

The tubing is suitably a downhole tubing and the created recesses using the method according to the present invention are advantageously utilized to hold at least one downhole device. Such a device is preferably a gas lift mandrel or a sensor. The downhole tubing is suitably situated within a completion liner or a

production casing and is selectively expanded without restricting the overall ID of the tubing.

The tubing may be made of almost all types of steel, but preferably the tubing is made of a high-strength steel grade with formability and having a yield strength-tensile strength ratio which is lower than 0.8 and a yield strength of at least 274 MPa. When used in this specification, the term high-strength steel denotes a steel with a yield strength of at least 275 MPa.

It is also preferred that the tubing is made of a formable steel grade having a yield stress/tensile stress ratio which is between 0.6 and 0.7.

Dual phase (DP) high-strength, low-alloy (HSLA) steels lack a definite yield point which eliminates Luders band formation during the tubular expansion process which ensures good surface finish of the expanded tubular.

Suitable HSLA dual phase (DP) steels for use in the method according to the invention are grades DP55 and DP60 developed by Sollac having a tensile strength of at least 550 MPa and grades SAFH 540 D and SAFH 590 D developed by Nippon Steel Corporation having a tensile strength of at least 540 MPa.

Other suitable steels are the following formable high-strength steel grades:

- an ASTM A106 high-strength low-alloy (HSLA) seamless pipe;
- an ASTM A312 austenitic stainless steel pipe, grade TP 304 L;
- an ASTM A312 austenitic stainless steel pipe, grade TP 316 L; and
- a high-retained austenite high-strength hot-rolled steel (low-alloy TRIP steel) such as grades SAFH 590 E, SAFH 690 E and SAFH 780 E developed by Nippon Steel Corporation.

The above-mentioned DP and other suitable steels each have a strain hardening exponent n of at least 0.16 which allows an expansion of the tubing such that the external diameter of the expanded tubing is at least 5% larger than the external diameter of the unexpanded tubing.

Detailed explanations of the terms strain hardening, work hardening and the strain hardening exponent n are given in chapters 3 and 17 of the handbook "Metal Forming-Mechanics and Metallurgy", 2nd edition, issued by Prentice Mail, New Jersey (USA), 1993.

Suitably, the tubing is selectively expanded such that the outer diameter of the selectively expanded tubing is slightly smaller than the internal diameter of a liner or casing that is present in the borehole and any fluids that are present in the borehole and tubing ahead of the expansion tool are vented to surface via the annular space that remains open around the tubing after/during the selective expansion process.

The invention also relates to a wellbore provided with a tubing which has been selectively expanded using the method according to the invention.

C L A I M S

1. A method of selective plastic expansion of sections of a tubing to create one or more recesses in the tubing with a larger diameter than that of the original tubing in which the tubing is radially symmetrically or asymmetrically expanded at one or more locations by application of a radial force to the interior of the tubing thereby inducing a plastic radial deformation of the tubing and removing said radial force from the interior of the tubing.

2. The method of claim 1, wherein the radial force to the interior of the tubing is exerted by means of an expandable tool.

3. The method of claim 1 or 2, wherein the expandable tool is an expandable mandrel or roller system, an expandable hydraulic packer or a steel reinforced bladder system, or the selective plastic expansion is achieved through a localized explosion or by means of hydraulic pressure in between two temporary seals.

4. The method of any preceding claim, wherein the expandable tool can be operated at an internal pressure of at least 200 bar.

5. The method of any preceding claim, wherein the tubing is a downhole tubing and the created recesses are utilized to hold at least one downhole device.

6. The method of any preceding claim, wherein the device is a gas lift mandrel or a sensor.

7. The method of any preceding claim, wherein the tubing is situated within a completion liner or a production casing and is selectively expanded without restricting the ID of the tubing.

8. The method of any preceding claim, wherein the tubing is made of a formable steel grade having a yield strength-tensile strength ratio which is lower than 0.8 and a yield strength of at least 275 MPa.

9. The method of claim 8, wherein the tubing is made of a steel having a yield strength-tensile strength ratio which is between 0.6 and 0.7.

10. The method of any preceding claim, wherein the tubing is made of a dual phase (DP) high-strength low-alloy (HSLA) steel.

11. The method of claim 10, wherein the tubing is made of Sollac grade DP55 or DP60 having a tensile strength of at least 550 MPa or Nippon grade SAFH 540 D and SAFH 590 D.

12. The method of claim 8, 9 or 10, wherein the tubing is made of a formable high-strength steel grade which is selected from the following group of steel grades:

- an ASTM A106 high-strength low-alloy (HSLA) seamless pipe;
- an ASTM A312 austenitic stainless steel pipe, grade TP 304 L;
- an ASTM A312 austenitic stainless steel pipe, grade TP 316 L; and
- a high-retained austenite high-strength hot-rolled steel, which is known as TRIP steel.

13. The method of any preceding claim, wherein the tubing is selectively expanded such that the external diameter of the selectively expanded tubing is at least 5% larger than the external diameter of the unexpanded tubing and wherein the strain hardening exponent n of the formable steel of the tubing is at least 0.16.

14. The method of any preceding claim, wherein the tubing is selectively expanded inside an underground borehole such that the outer diameter of the selectively expanded tubing is slightly smaller than the internal diameter of a casing that is present in the borehole and any fluids

that are present in the borehole and tubing ahead of the expansion tool are vented to surface via the annular space that remains open around the tubing after the selective expansion process.

15. The method of any preceding claim, wherein the tubing is lowered into an underground borehole after reeling the tubing from a reeling drum.

16. A well provided with a tubing which is selectively expanded using the method of any preceding claim.

INTERNATIONAL SEARCH REPORT

Inte. ..ional Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B29/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 720 262 A (GRABLE D) 13 March 1973 (1973-03-13) column 6, line 60 -column 7, line 9 ---	1-3,5,7, 14,16
X	CH 609 401 A (GRUND UND TIEFBAU AG BERN) 28 February 1979 (1979-02-28) page 2, column 2, line 28 - line 50 ---	1-3
A	GB 2 276 648 A (HALLIBURTON CO) 5 October 1994 (1994-10-05) abstract; figures 9,9A,9B -----	1-16

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte. .ional Application No
PCT/EP 00/03104

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 3720262	A	13-03-1973	NONE			
CH 609401	A	28-02-1979	NONE			
GB 2276648	A	05-10-1994	US	5390742	A	21-02-1995
			CA	2120108	A	01-10-1994
			SG	47824	A	17-04-1998